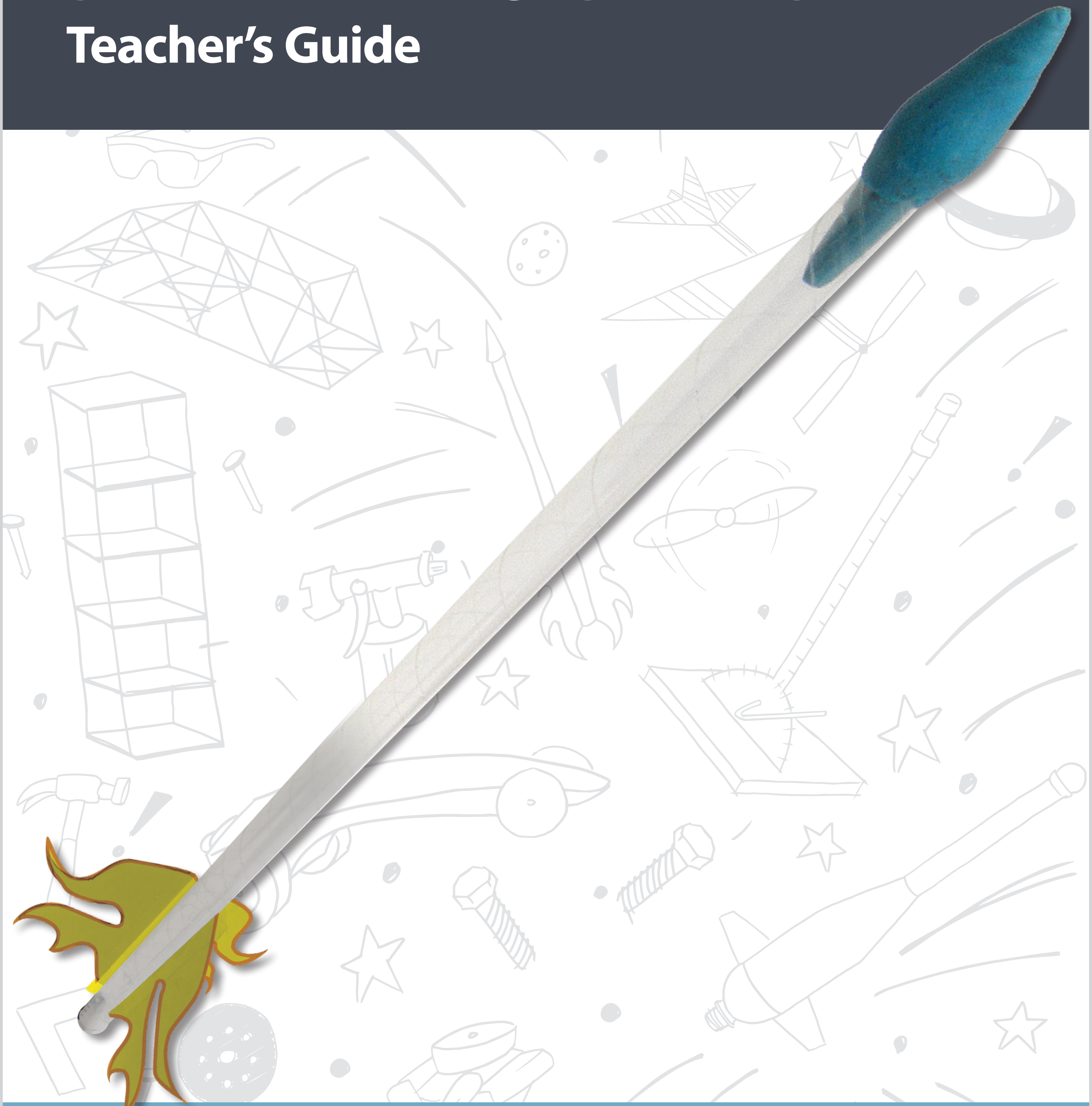
STRAW ROCKETS

Teacher's Guide



STEM Curriculum for Straw Rockets

PITSCO EDUCATION

45140

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Creativity *Critical Thinking* *Communication* *Collaboration* *Back to Last Page Viewed* *Table of Contents*

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Activity Overview

Using the provided kit materials, students design and construct a rocket from a precision straw.

The *Straw Rockets Teacher's Guide* contains both basic and advanced lesson plans. Basic lesson plans provide a more guided approach to instruction while advanced lesson plans are more open-ended. All lesson plans can be used to extend students' understanding of science, technology, engineering, and math concepts using the straw rocket.

Resource materials are provided to supplement students' understanding of core content. Resources include vocabulary, assessments, and content fact sheets.

Materials

This section lists required or optional materials and equipment for activities found in this guide. The first section lists materials and equipment needed for all activities. The second section lists optional materials and equipment, including class packs for replenishing consumables. If you are planning to complete only select activities, refer to the materials list located in each activity. Links are provided to Pitsco products for your convenience and offer at least one option. Other options might be available; to explore them, use the search box on Pitsco.com.

All Materials and Equipment Needed for All Activities

- Straw Rockets – Getting Started Package: Pitsco.com/Straw-Rockets-Getting-Started-Package
  - Straw Rocket Class Pack: Pitsco.com/Straw-Rocket-Class-Pack
    - Precision Straws: Pitsco.com/Precision-Straws
    - Index cards: Pitsco.com/Index-Cards-3x5
    - Modeling clay: Pitsco.com/Modeling-Clay
  - Straw Rocket Launcher: Pitsco.com/Straw-Rocket-Launcher
  - *Straw Rocket* video: Pitsco.com/Straw-Rocket-Video
- Calculator: Pitsco.com/Basic-Calculator
- Digital scale: Pitsco.com/CJ600-Digital-Scale
- Graph paper: Pitsco.com/Graph-Paper
- Notebook
- Pencil
- Ruler: Pitsco.com/12-Metric-English-Aluminum-Ruler
- Scissors: Pitsco.com/Super-Sharp-Scissors-8
- Stopwatch: Pitsco.com/Pro-Survivor-Stopwatch
- Tape measure: Pitsco.com/30-Meter-Wind-Up-Tape-Measure
- Transparent tape: Pitsco.com/Transparent-Tape

Optional Materials and Equipment

- Caplugs: Pitsco.com/Caplugs
  Note: Caplugs may replace the modeling clay nose cones on the straw rockets except in activities where the nose cone is the independent variable. Caplugs alleviate the potential mess from students using modeling clay.
- Engineering Design Loop Poster: Pitsco.com/Engineering-Design-Loop-Poster-Set
- Mini Straw Rocket Launcher: Pitsco.com/Mini-Straw-Rocket-Launcher
  Note: This launcher is not recommended for activities within this guide as the accuracy and consistency of launches cannot be maintained. It is, however, useful for activities where only general observations are needed.
- Range paper: Pitsco.com/Range-Paper
  Note: Range paper may be used to assist students in determining where their straw rocket landed.
- Straw Rocket Maker Project: Pitsco.com/Straw-Rocket-Maker-Project
  Note: The Straw Rocket Maker Project includes three Straw Rocket Launchers, a Straw Rocket Class Pack, and a storage bin for the straw rocket materials.

Activities with the following icons include opportunities for students to apply 21st-century skills in communication, collaboration, critical thinking, and creativity. If time is available, you might choose to focus on these skills in conjunction with the activities. These icons will appear in the Procedure sections of the Teacher Instruction. Additional icons might appear in the Note section that suggest how an additional skill can be addressed in the activity.

Communication	Sharing thoughts, questions, ideas, and solutions. Indicators: • Articulate thoughts and ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts • Listen effectively to decipher meaning, including knowledge, values, attitudes and intentions • Use communication for a range of purposes (e.g. to inform, instruct, motivate and persuade) • Utilize multiple media and technologies, and know how to judge their effectiveness a priori as well as assess their impact • Communicate effectively in diverse environments (including multi-lingual)
Collaboration	Working together to reach a goal – putting talent, expertise, and smarts to work. Indicators: • Demonstrate ability to work effectively and respectfully with diverse teams • Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal • Assume shared responsibility for collaborative work, and value the individual contributions made by each team member
Critical Thinking	Looking at problems in a new way, linking learning across subjects and disciplines. Indicators: **Reason Effectively** • Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation **Use Systems Thinking** • Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems **Make Judgments and Decisions** • Effectively analyze and evaluate evidence, arguments, claims and beliefs • Analyze and evaluate major alternative points of view • Synthesize and make connections between information and arguments • Interpret information and draw conclusions based on the best analysis • Reflect critically on learning experiences and processes **Solve Problems** • Solve different kinds of non-familiar problems in both conventional and innovative ways • Identify and ask significant questions that clarify various points of view and lead to better solutions
Creativity	Trying new approaches to get things done equals innovation and invention. Indicators: **Think Creatively** • Use a wide range of idea creation techniques (such as brainstorming) • Create new and worthwhile ideas (both incremental and radical concepts) • Elaborate, refine, analyze and evaluate their own ideas in order to improve and maximize creative efforts **Work Creatively with Others** • Develop, implement and communicate new ideas to others effectively • Be open and responsive to new and diverse perspectives; incorporate group input and feedback into the work • Demonstrate originality and inventiveness in work and understand the real-world limits to adopting new ideas • View failure as an opportunity to learn; understand that creativity and innovation is a long-term, cyclical process of small successes and frequent mistakes **Implement Innovations** • Act on creative ideas to make a tangible and useful contribution to the field in which the innovation will occur

Source: Partnership for 21st Century Skills: Pitsco.com/c-4cs-research

Standards Addressed

Standards were taken from the International Technology and Engineering Educators Association (ITEEA), the Next Generation Science Standards (NGSS), and the Common Core State Standards (CCSS).

NGSS

NGSS.MS.FI Forces and Interactions

NGSS.MS-PS2-2
Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

NGSS.MS.ED Engineering Design

NGSS.MS-ETS1-1
Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

NGSS.MS-ETS1-2
Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

NGSS.MS-ETS1-3
Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

NGSS.MS-ETS1-4
Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

CCSS.MATH

Grade 6

CCSS.MATH.CONTENT.6.RP.A
Understand ratio concepts and use ratio reasoning to solve problems.

CCSS.MATH.CONTENT.6.RP.A.3
Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.

CCSS.MATH.CONTENT.6.RP.A.3.A
Make tables of equivalent ratios relating quantities with whole-number measurements, find missing values in the tables, and plot the pairs of values on the coordinate plane. Use tables to compare ratios.

CCSS.MATH.CONTENT.6.RP.A.3.D
Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.

CCSS.MATH.CONTENT.6.NS.B
Compute fluently with multi-digit numbers and find common factors and multiples.

CCSS.MATH.CONTENT.6.NS.B.2
Fluently divide multi-digit numbers using the standard algorithm.

CCSS.MATH.CONTENT.6.EE.B
Reason about and solve one-variable equations and inequalities.

CCSS.MATH.CONTENT.6.EE.B.6
Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.

CCSS.MATH.CONTENT.6.EE.C
Represent and analyze quantitative relationships between dependent and independent variables.

CCSS.MATH.CONTENT.6.EE.C.9
Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.

Grade 7

CCSS.MATH.CONTENT.7.RP.A
Analyze proportional relationships and use them to solve real-world and mathematical problems.

CCSS.MATH.CONTENT.7.RP.A.2
Recognize and represent proportional relationships between quantities.

CCSS.MATH.CONTENT.7.RP.A.2.A
Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.

CCSS.MATH.CONTENT.7.EE.B
Solve real-life and mathematical problems using numerical and algebraic expressions and equations.

CCSS.MATH.CONTENT.7.EE.B.4
Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

CCSS.MATH.CONTENT.7.SP.A
Use random sampling to draw inferences about a population.

CCSS.MATH.CONTENT.7.SP.A.1
Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.

Grade 8

CCSS.MATH.CONTENT.8.SP.A
Investigate patterns of association in bivariate data.

CCSS.MATH.CONTENT.8.SP.A.1
Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

CCSS.MATH.CONTENT.8.SP.A.4
Understand that patterns of association can also be seen in bivariate categorical data by displaying frequencies and relative frequencies in a two-way table. Construct and interpret a two-way table summarizing data on two categorical variables collected from the same subjects. Use relative frequencies calculated for rows or columns to describe possible association between the two variables.

ITEEA

ITEEA.9.H
Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.

ITEEA.11.H
Apply a design process to solve problems in and beyond the laboratory-classroom.

ITEEA.11.L
Make a product or system and document the solution.

ITEEA.13.F
Design and use instruments to gather data.

Construction Quick View

Students use kit materials to construct a straw rocket following the steps below. Students determine fin shape, number of fins, rocket length, and nose cone shape. Below are the design constraints that need to be considered for every rocket constructed:

- Rockets should have a minimum of two fins and a maximum of five fins.
- The body of the rocket should be a minimum length of 10 centimeters and a maximum length of 20 centimeters.
- The amount of clay used for the nose cone should have a maximum diameter of two centimeters when rolled into a ball.

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Pencil
- Ruler
- Scissors
- Transparent tape

Construction

1. Sketch the rocket design on a piece of paper, starting with the rocket body, proceeding to the fins, and finishing with the nose cone.
2. Draw the chosen fin shape on an index card, drawing as many fins as needed for the rocket design.
3. Cut the fins out of the index card. The fins should all be the same size and shape.
4. Cut the straw to the desired length with the scissors.
5. Cut a piece of tape as long as the edge of the fin that is to be connected to the rocket body or straw. Place the tape on the edge of one fin. Repeat this for all fins. Attach the fins so they are evenly spaced around the straw. Trim off any excess tape using the scissors.
6. Knead the clay to soften it. Carefully shape the clay to match the desired nose cone shape. The surface of the nose cone needs to be smooth. Press the nose cone on top of the straw rocket body, making sure the nose cone is centered. The outside edge between the straw and nose cone should be sealed carefully with the clay.
7. Launch the straw rocket using Pitsco's Straw Rocket Launcher.

Teaching Tips

Safety

- The students should never launch straw rockets at people. Before a straw rocket is launched, clear all people from the rocket's theoretical flight path.
- Sharp objects such as needles and pins should never be attached to a straw rocket.
- When rockets are launched, simply release or drop the launch rod. Avoid forcing the rod into the cylinder.
- Supervise students while they launch straw rockets.

Construction Tips/Helpful Hints

- The straw will form the body of the rocket. Test the straw on the launcher to ensure that it is the right size. The straw should fit over the tube and be able to slide freely up and down. If the straw is too loose, however, air will leak between the straw and the tube and decrease the distance the rocket will travel.
- Straw packages do not usually list the diameter. However, a 1/4" diameter straw will often be listed as a "large" straw. To ensure the straws are the exact diameter needed, use Pitsco's Precision Straws (59241).
- Varying fin design, placement, and number; body tube length; nose cone shape and mass; and overall center of gravity can affect the rocket's flight. You might allow students to experiment with their rocket design.
- Varying the placement of the rocket on the launch tube will also affect the rocket's flight. You might allow students to experiment with their rocket placement on the launch tube. The small black O-ring on the launch tube can be moved to adjust where the rocket sits on the tube.
- Launches need to be performed on a smooth, flat surface such as the floor. There also needs to be room for the rocket to launch – a school gymnasium is ideal.

Troubleshooting

- If Pitsco's Straw Rocket Launcher has been stored without being used for several months or if the piston's movement becomes erratic, the O-ring inside the launch cylinder might need to be relubricated. To relubricate the O-ring, see the directions included with the launcher.
- If the rocket will not launch, there might be a gap between the nose cone and the straw. If this is the case, air will travel through the gap instead of forcing the rocket to launch.
- Another reason the rocket might not launch could be the rocket's mass. If you think the rocket will not launch because it is too heavy, try raising the launch rod to a higher calibration mark (calibration marks are the lines on the launch rod).
- If the rocket appears to be top-heavy or wobbles, the nose cone is unstable. You can easily fix this by removing some of the clay and reshaping the nose cone.
- If clay gets stuck in the straw, you can use a toothpick to remove it.
- Contact Pitsco Customer Service if the launch tube gets bent or if the launcher does not launch rockets properly (especially if the launcher has been pulled apart accidentally).

Quick View

Students vary the length of a straw rocket to investigate the effect length has on the rocket's range.

Time Required

45-90 minutes (will vary with class size)

Content Areas

Primary: Technology

Secondary: Math, science, language arts

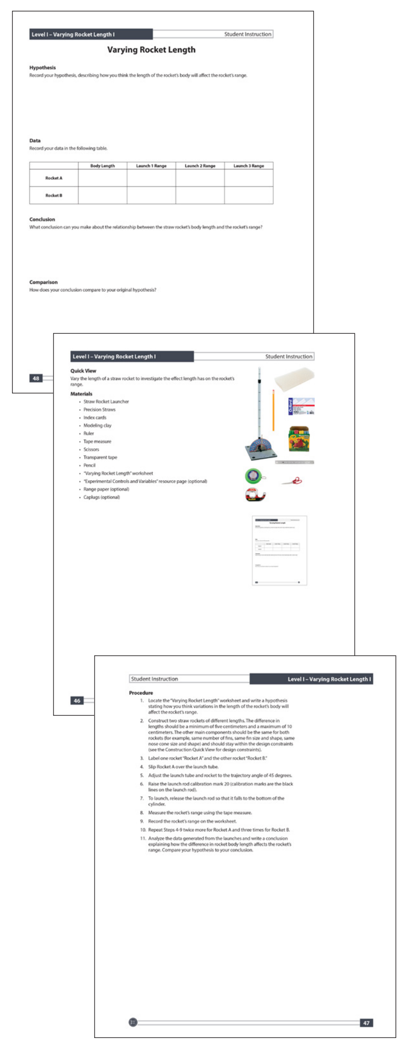
Vocabulary

Glossary: Pitsco.com/c/sr-glossary.pdf

- altitude
- apogee
- conclusion
- constraint
- control
- design
- fin
- hypothesis
- nose cone
- range
- rocket
- trajectory
- variable

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- "Varying Rocket Length" worksheet: Pitsco.com/c/sr-sp3.pdf
- Varying Rocket Length I Student Instructions: Pitsco.com/c/sr-sp2.pdf
- "Experimental Controls and Variables" resource page (optional): Pitsco.com/c/experimental-controls-variables.pdf
- Range paper (optional)
- Caplugs (optional)



Procedure

1. Locate the "Varying Rocket Length" worksheet and write a hypothesis stating how you think variations in the length of the rocket's body will affect the rocket's range.

Note: (1) Middle school students should understand the term *hypothesis*. However, you might wish to explain that a hypothesis is a prediction based on prior knowledge or experience.

2. Construct two straw rockets of different lengths. The difference in lengths should be a minimum of five centimeters and a maximum of 10 centimeters. The other main components should be the same for both rockets (for example, same number of fins, same fin size and shape, same nose cone size and shape) and should stay within the design constraints (see the Construction Quick View for design constraints).

Note: (2) In this experiment the variable is the length of the rocket body, and the controls are the fins and nose cone.

3. Label one rocket "Rocket A" and the other rocket "Rocket B."

Note: (3) The rockets can be labeled by using a marker on the rocket body, by using a piece of tape, or by writing on one of the fins.

4. Slip Rocket A over the launch tube.
5. Adjust the launch tube and rocket to the trajectory angle of 45 degrees.
6. Raise the launch rod calibration mark 20 (calibration marks are the black lines on the launch rod).
7. To launch, release the launch rod so that it falls to the bottom of the cylinder.
8. Measure the rocket's range using the tape measure.

Note: (8) You might choose to have students measure in metric or standard measurements. The tape measure listed in the materials and equipment has both units of measure.

9. Record the rocket's range on the worksheet.
10. Repeat Steps 4-9 twice more for Rocket A and three times for Rocket B.
11. Analyze the data generated from the launches and write a conclusion explaining how the difference in rocket body length affects the rocket's range. Compare your hypothesis to your conclusion.

Note: (11) Conclusions should be supported by data.

Quick View

Students vary the mass of the nose cone to investigate the effect on the rocket's range.

Time Required

45-90 minutes (will vary with class size)

Content Areas

Primary: Science

Secondary: Math, technology, language arts

Vocabulary

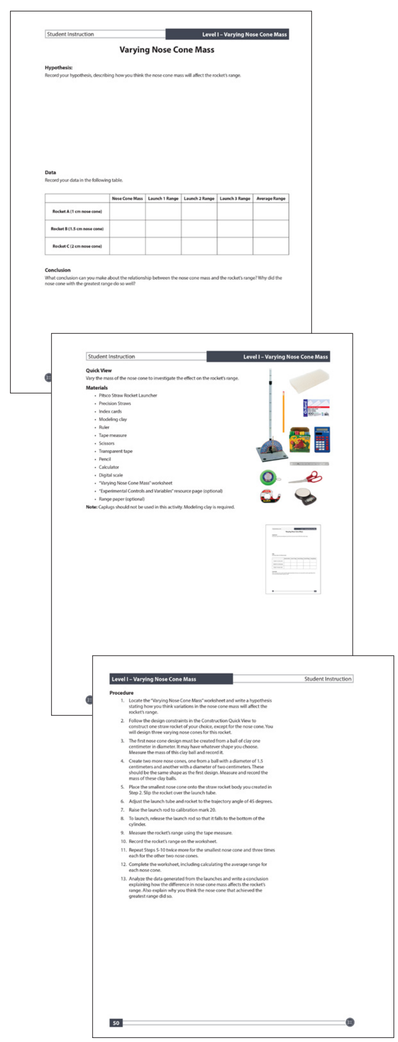
Glossary: Pitsco.com/c/sr-glossary.pdf

- average
- control
- diameter
- hypothesis
- mass
- nose cone
- variable

Materials

- Pitsco Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- Calculator
- Digital scale
- "Varying Nose Cone Mass" worksheet: Pitsco.com/c/sr-sp5.pdf
- Varying Nose Cone Mass Student Instruction: Pitsco.com/c/sr-sp4.pdf
- "Experimental Controls and Variables" resource page (optional): Pitsco.com/c/experimental-controls-variables.pdf
- Range paper (optional)

Note: Caplugs should not be used in this activity. Modeling clay is required.


Student Instruction
Level I – Varying Nose Cone Mass

Varying Nose Cone Mass

Hypothesis:
Record your hypothesis, describing how you think the nose cone mass will affect the rocket's range.

Data
Record your data in the following table.

	Nose Cone Mass	Launch 1 Range	Launch 2 Range	Launch 3 Range	Average Range
Rocket A (1 cm nose cone)					
Rocket B (1.5 cm nose cone)					
Rocket C (2 cm nose cone)					

Conclusion
What conclusion can you make about the relationship between the nose cone mass and the rocket's range? Why did the nose cone with the greatest range do so well?

Student Instruction
Level I – Varying Nose Cone Mass

Quick View
Vary the mass of the nose cone to investigate the effect on the rocket's range.

Procedure

In this activity the student will use one rocket but will change out the nose cone three times. If the clay cannot be easily removed from the straw, try cleaning it out with a toothpick or something similar. If that does not work, the student might have to construct a new rocket.

1. Locate the "Varying Nose Cone Mass" worksheet and write a hypothesis stating how you think variations in the nose cone mass will affect the rocket's range.
2. Follow the design constraints in the Construction Quick View to construct one straw rocket of your choice, except for the nose cone. You will design three varying nose cones for this rocket.
3. The first nose cone design must be created from a ball of clay one centimeter in diameter. It may have whatever shape you choose. Measure the mass of this clay ball and record it.
4. Create two more nose cones, one from a ball with a diameter of 1.5 centimeters and another with a diameter of two centimeters. These should be the same shape as the first design. Measure and record the mass of these clay balls.
5. Place the smallest nose cone onto the straw rocket body you created in Step 2. Slip the rocket over the launch tube.
6. Adjust the launch tube and rocket to the trajectory angle of 45 degrees.
7. Raise the launch rod to calibration mark 20.
8. To launch, release the launch rod so that it falls to the bottom of the cylinder.
9. Measure the rocket's range using the tape measure.
10. Record the rocket's range on the worksheet.
11. Repeat Steps 5-10 twice more for the smallest nose cone and three times each for the other two nose cones.
12. Complete the worksheet, including calculating the average range for each nose cone.
13. Analyze the data generated from the launches and write a conclusion explaining how the difference in nose cone mass affects the rocket's range. Also explain why you think the nose cone that achieved the greatest range did so.

Note: (1) Middle school students should understand the term *hypothesis*. However, you might wish to explain that a hypothesis is a prediction based on prior knowledge or experience.

Note: (3) This diameter has to be for the nose cone only when it is in the shape of a ball. After that, the student may shape the nose cone to their discretion.

Note: (4) You should point out to students the differences between controls and variables. In this experiment, the variable is the nose cone mass, and the controls are the fins and body length.

Note: (9) You might choose to have students measure in metric or standard measurements. The tape measure listed in the materials and equipment has both units of measure.

Note: (13) Conclusions should be supported by data.

Quick View

Students vary the angle of launch to investigate the effects angle has on the rocket's range.

Time Required

90-180 minutes (will vary with class size)

Content Areas

Primary: Math

Secondary: Technology, science, language arts

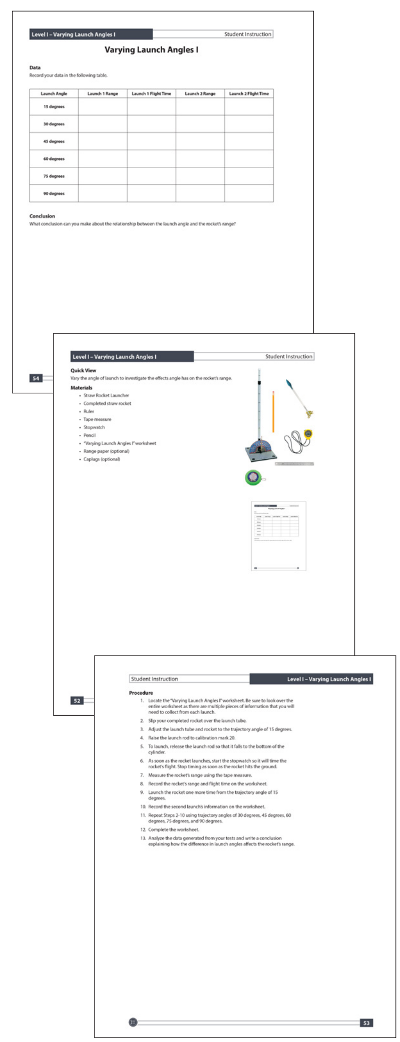
Vocabulary

Glossary: Pitsco.com/c/sr-glossary.pdf

- angle
- constraint
- design
- projectile
- trajectory

Materials

- Straw Rocket Launcher
- Completed straw rocket
- Ruler
- Tape measure
- Stopwatch
- Pencil
- "Varying Launch Angles I" worksheet: Pitsco.com/c/sr-sp7.pdf
- Varying Launch Angles I Student Instruction: Pitsco.com/c/sr-sp6.pdf
- Range paper (optional)
- Caplugs (optional)



Procedure

1. Locate the "Varying Launch Angles I" worksheet. Be sure to look over the entire worksheet as there are multiple pieces of information that you will need to collect from each launch.
2. Slip your completed rocket over the launch tube.
3. Adjust the launch tube and rocket to the trajectory angle of 15 degrees.
4. Raise the launch rod to calibration mark 20.
5. To launch, release the launch rod so that it falls to the bottom of the cylinder.
6. As soon as the rocket launches, start the stopwatch so it will time the rocket's flight. Stop timing as soon as the rocket hits the ground.
7. Measure the rocket's range using the tape measure.
8. Record the rocket's range and flight time on the worksheet.
9. Launch the rocket one more time from the trajectory angle of 15 degrees.
10. Record the second launch's information on the worksheet.
11. Repeat Steps 2-10 using trajectory angles of 30 degrees, 45 degrees, 60 degrees, 75 degrees, and 90 degrees.
12. Complete the worksheet.
13. Analyze the data generated from your tests and write a conclusion explaining how the difference in launch angles affects the rocket's range.

Note: (1) Students might need a partner for this activity. One person can perform the launch, and the second person can run the stopwatch.

Note: (6) You might want to have students practice using the stopwatch with launches prior to actual data collection.

Note: (7) You might choose to have students measure in metric or standard measurements. The tape measure listed in the materials and equipment has both units of measure.

Note: (11) The rocket might bounce after it hits the ground. Students should measure to the initial contact point.

Quick View

Students design a straw rocket that will achieve the greatest range possible.

Time Required

180-260 minutes (will vary with class size)

Content Areas

Primary: Technology

Secondary: Math, science, language arts

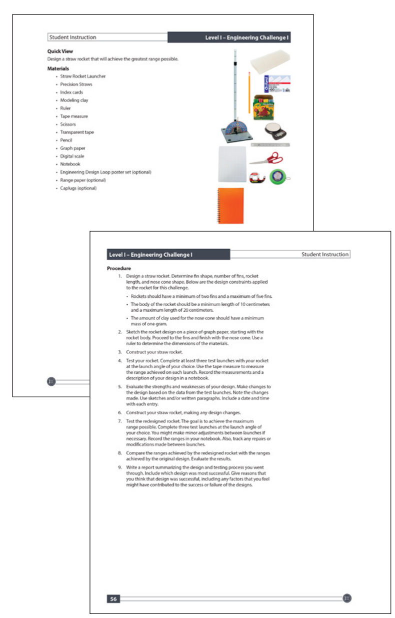
Vocabulary

Glossary: Pitsco.com/c/sr-glossary.pdf

- constraint
- design
- diameter
- mass
- modification
- nose cone

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- Graph paper
- Digital scale
- Notebook
- Engineering Challenge I Student Instruction: Pitsco.com/c/sr-sp8.pdf
- Engineering Design Loop poster set (optional)
- Range paper (optional)
- Caplugs (optional)



Procedure

At this point, students should have completed activities in which they test the differences in rocket body length, nose cone mass, and launch angles. Students should use past data in designing the rocket for this challenge.

1. Design a straw rocket. Determine fin shape, number of fins, rocket length, and nose cone shape. Below are the design constraints applied to the rocket for this challenge.
   - Rockets should have a minimum of two fins and a maximum of five fins.
   - The body of the rocket should be a minimum length of 10 centimeters and a maximum length of 20 centimeters.
   - The amount of clay used for the nose cone should have a minimum mass of one gram.
2. Sketch the rocket design on a piece of graph paper, starting with the rocket body. Proceed to the fins and finish with the nose cone. Use a ruler to determine the dimensions of the materials.
3. Construct your straw rocket.
4. Test your rocket. Complete at least three test launches with your rocket at the launch angle of your choice. Use the tape measure to measure the range achieved on each launch. Record the measurements and a description of your design in a notebook.

Note: (4) Depending on the level of the students, you might need to demonstrate some possibilities for keeping a log of designs and design modifications. One method would be to keep a notebook with sketches, data, materials, and explanations of changes with dates and times for each entry. You might wish to create a structured format for students to do this, or you might choose to give them an example and allow them to approach the record keeping in a more free-form style.

5. Evaluate the strengths and weaknesses of your design. Make changes to the design based on the data from the test launches. Note the changes made. Use sketches and/or written paragraphs. Include a date and time with each entry.

Note: (5) This is an opportunity to talk about design iterations as students modify their designs to acheive the greatest range possible. Pitsco's Engineering Design Loop poster set provides a good introduction to this process.

6. Construct your straw rocket, making any design changes.
7. Test the redesigned rocket. The goal is to achieve the maximum range possible. Complete three test launches at the launch angle of your choice. You might make minor adjustments between launches if necessary. Record the ranges in your notebook. Also, track any repairs or modifications made between launches.
8. Compare the ranges achieved by the redesigned rocket with the ranges achieved by the original design. Evaluate the results.
9. Write a report summarizing the design and testing process you went through. Include which design was most successful. Give reasons that you think that design was successful, including any factors that you feel might have contributed to the success or failure of the designs.

Note: (9) You might wish to give students a structured format to use for the report. They should identify the design problem, the proposed solution, the steps used to test the proposed solution, any design modifications made, the retesting procedures, the testing results, and their evaluation of the design solution.

Quick View

Students experiment with the length of a straw rocket to test the effect length has on the rocket's range.

Time Required

90-180 minutes (will vary with class size)

Content Areas

Primary: Technology

Secondary: Math, science, language arts

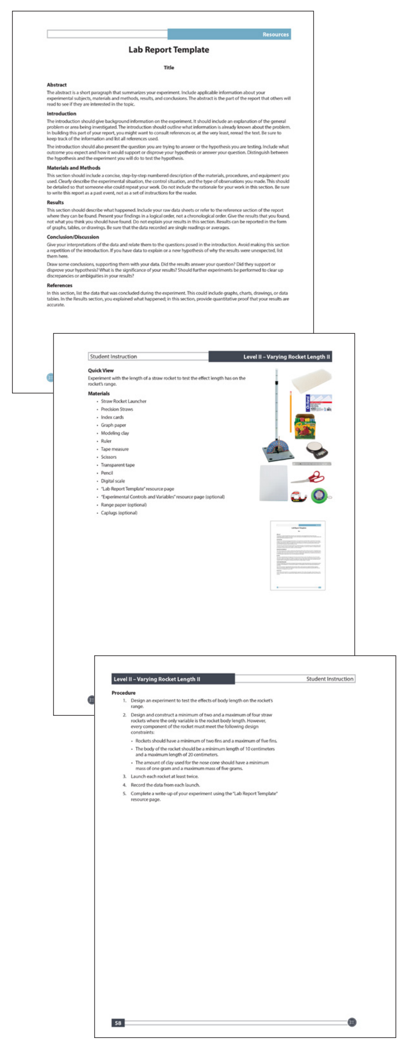
Vocabulary

Glossary: Pitsco.com/c/sr-glossary.pdf

- conclusion
- constraint
- control
- design
- fin
- hypothesis
- nose cone
- range
- trajectory
- variable

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Graph paper
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- Digital scale
- "Lab Report Template" resource page: Pitsco.com/c/labreport.pdf
- Varying Rocket Length II Student Instruction: Pitsco.com/c/sr-sp9.pdf
- "Experimental Controls and Variables" resource page (optional): Pitsco.com/c/experimental-controls-variables.pdf
- Range paper (optional)
- Caplugs (optional)



Procedure

1. Design an experiment to test the effects of body length on the rocket's range.

2. Design and construct a minimum of two and a maximum of four straw rockets where the only variable is the rocket body length. However, every component of the rocket must meet the following design constraints:

    - Rockets should have a minimum of two fins and a maximum of five fins.
    - The body of the rocket should be a minimum length of 10 centimeters and a maximum length of 20 centimeters.
    - The amount of clay used for the nose cone should have a minimum mass of one gram and a maximum mass of five grams.

3. Launch each rocket at least twice.

4. Record the data from each launch.

5. Complete a write-up of your experiment using the "Lab Report Template" resource page.

Note: (2) In this experiment, the variable is the length of the rocket body, and the controls are the fins, nose cone, launch angle, and launch rod calibration mark. Remind students that the mass and shape of the nose cone should be the same for all their rockets.

Note: (3) To launch the rocket, slip the first rocket over the launch tube. Adjust the launch tube and rocket to the desired trajectory angle. Raise the launch rod to the desired calibration mark. Release the launch rod so that it falls to the bottom of the cylinder.

Quick View

Students change the mass of a straw rocket to increase the rocket's range.

Time Required

90-180 minutes (will vary with class size)

Content Areas

Primary: Science

Secondary: Math, technology, language arts

Vocabulary

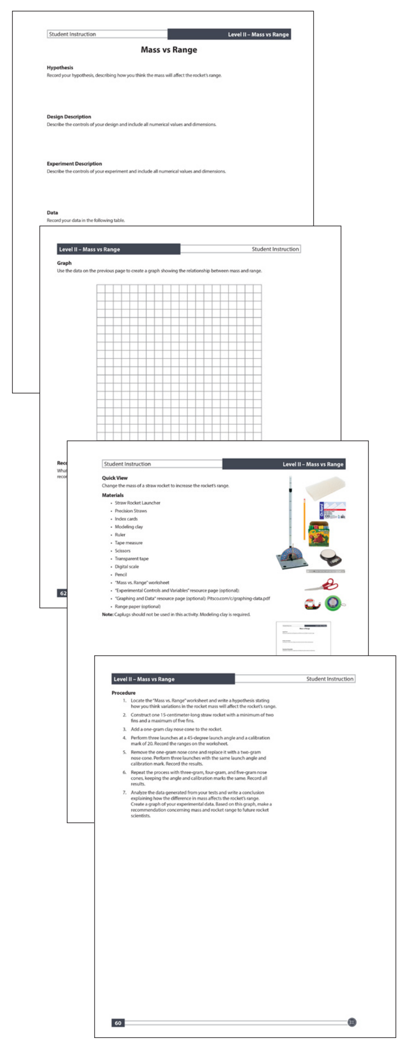
Glossary: Pitsco.com/c/sr-glossary.pdf

- control
- hypothesis
- mass
- nose cone
- scatter plot
- variable
- weight

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Digital scale
- Pencil
- "Mass vs. Range" worksheet: Pitsco.com/c/sr-sp11.pdf
- Mass vs Range Student Instructions: Pitsco.com/c/sr-sp10.pdf
- "Experimental Controls and Variables" resource page (optional): Pitsco.com/c/experimental-controls-variables.pdf
- "Graphing and Data" resource page (optional): Pitsco.com/c/graphing-data.pdf
- Range paper (optional)

Note: Caplugs should not be used in this activity. Modeling clay is required.



Procedure

1. Locate the "Mass vs. Range" worksheet and write a hypothesis stating how you think variations in the rocket mass will affect the rocket's range.
2. Construct one 15-centimeter-long straw rocket with a minimum of two fins and a maximum of five fins.
3. Add a one-gram clay nose cone to the rocket.
4. Perform three launches at a 45-degree launch angle and a calibration mark of 20. Record the ranges on the worksheet.
5. Remove the one-gram nose cone and replace it with a two-gram nose cone. Perform three launches with the same launch angle and calibration mark. Record the results.
6. Repeat the process with three-gram, four-gram, and five-gram nose cones, keeping the angle and calibration marks the same. Record all results.
7. Analyze the data generated from your tests and write a conclusion explaining how the difference in mass affects the rocket's range. Create a graph of your experimental data. Based on this graph, make a recommendation concerning mass and rocket range to future rocket scientists.

Note: (1) The definitions for *weight* and *mass* can be found in the glossary. Students should use metric measurements within this activity.

Note: (7) Conclusions should be supported by data. Suggest to students that they graph the data using a scatter plot.

Quick View

Students experiment with the launch angle of a straw rocket to test the effect angle has on the rocket's range.

Time Required

90-180 minutes (will vary with class size)

Content Areas

Primary: Math

Secondary: Technology, science, language arts

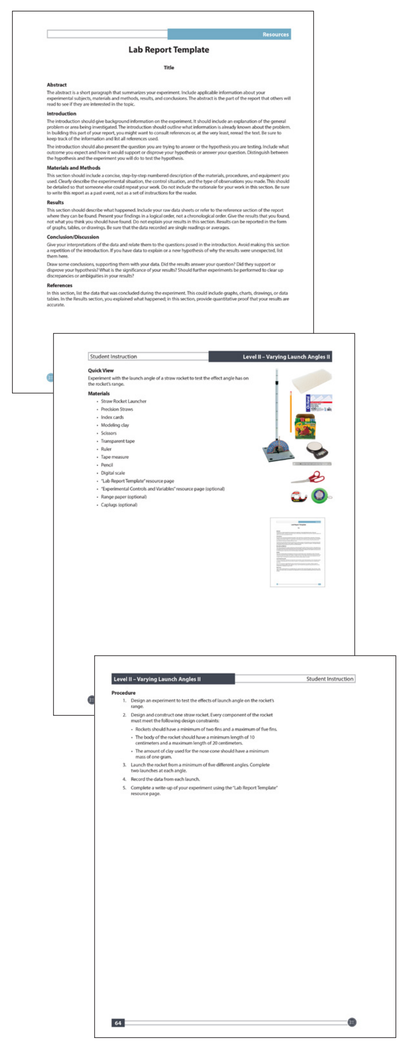
Vocabulary

Glossary: Pitsco.com/c/sr-glossary.pdf

- conclusion
- constraint
- control
- design
- fin
- hypothesis
- nose cone
- projectile
- range
- trajectory
- variable

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Scissors
- Transparent tape
- Ruler
- Tape measure
- Pencil
- Digital scale
- "Lab Report Template" resource page: Pitsco.com/c/labreport.pdf
- Varying Launch Angles II Student Instruction: Pitsco.com/c/sr-sp12.pdf
- "Experimental Controls and Variables" resource page (optional) Pitsco.com/c/experimental-controls-variables.pdf
- Range paper (optional)
- Caplugs (optional)



Procedure

1. Design an experiment to test the effects of launch angle on the rocket's range.
2. Design and construct one straw rocket. Every component of the rocket must meet the following design constraints:
   - Rockets should have a minimum of two fins and a maximum of five fins.
   - The body of the rocket should have a minimum length of 10 centimeters and a maximum length of 20 centimeters.
   - The amount of clay used for the nose cone should have a minimum mass of one gram.
3. Launch the rocket from a minimum of five different angles. Complete two launches at each angle.
4. Record the data from each launch.
5. Complete a write-up of your experiment using the "Lab Report Template" resource page.

Note: (2) In this experiment, the variable is the launch angle, and the controls are the length of the rocket body, fins, nose cone, and launch rod calibration mark.

Note: (3) Students might need to be reminded to launch all the rockets at the same launch rod calibration mark to keep the controlled variable constant.

Quick View

Students design a straw rocket that will achieve a specified range.

Time Required

225-550 minutes (will vary with class size)

Content Areas

Primary: Technology

Secondary: Math, science, language arts

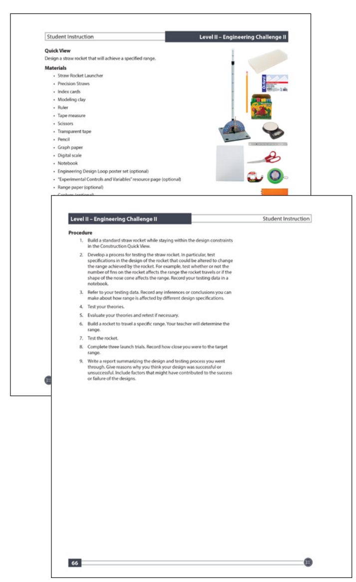
Vocabulary

Glossary: Pitsco.com/c/sr-glossary.pdf

- constraint
- design
- inference
- modification

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- Graph paper
- Digital scale
- Notebook
- Engineering Challenge II Student Instruction: Pitsco.com/c/sr-sp13.pdf
- Engineering Design Loop poster set (optional)
- “Experimental Controls and Variables” resource page (optional) Pitsco.com/c/experimental-controls-variables.pdf
- Range paper (optional)
- Caplugs (optional)


Student Instruction
Level II – Engineering Challenge II
Quick View
Materials
Procedure

Procedure

1. Build a standard straw rocket while staying within the design constraints in the Construction Quick View.

2. Develop a process for testing the straw rocket. In particular, test specifications in the design of the rocket that could be altered to change the range achieved by the rocket. For example, test whether or not the number of fins on the rocket affects the range the rocket travels or if the shape of the nose cone affects the range. Record your testing data in a notebook.

Note: (2) Students should record the testing procedure in a scientific format. They could follow a standard scientific method layout, or they could use a modified problem-solving format. It is important that the students clearly identify what specifications of the design they are testing, how they are testing the specifications, and what the results of the tests are. You might wish to have students bring a notebook, or you could duplicate and place templates from this guide in a binder. Students should get in the practice of keeping track of ideas, testing procedures, and data.

3. Refer to your testing data. Record any inferences or conclusions you can make about how range is affected by different design specifications.

Note: (3) You might want to discuss with your students what inferences are, how they are made, and how to tell if they are reasonable. This should be fairly simple, but some students will need to be reminded how to make a reasonable inference from testing data.

4. Test your theories.

Note: (4) Students should test their inferences and/or conclusions using their original rocket design. For example, if they infer that the number of fins on the rocket influences the distance traveled by the rocket, they should change the number of fins and test this theory.

5. Evaluate your theories and retest if necessary.

Note: (5) This is an opportunity to talk about design iterations as students modify their designs to achieve the greatest range possible. Pitsco's Engineering Design Loop poster set provides a good introduction to this process.

6. Build a rocket to travel a specific range. Your teacher will determine the range.

Note: (6) For this part of the process, you will need to determine a range for the rockets to achieve. A range between five and 20 meters is recommended. You will also need to specify the launch angle and the calibration mark to be used for the launch. This can be made into a mini competition or kept as an individual challenge.

7. Test the rocket.

> **Note: (7)** After building the rocket to meet the challenge you have set forth, students should get a chance to test their rockets before the challenge.

8. Complete three launch trials. Record how close you were to the target range.

> **Note: (8)** Give students three chances to reach the challenge range. You might even want to give a prize to the student that comes closest to the target range.

9. Write a report summarizing the design and testing process you went through. Give reasons why you think your design was successful or unsuccessful. Include factors that might have contributed to the success or failure of the designs.

> **Note: (9)** Students' reports should follow rules of grammar, punctuation, and spelling and be technically accurate.

Supplemental Lessons

Listed below are ideas for other lessons that can be developed to engage and challenge students with materials and equipment used in this teacher guide. Suggestions can be combined by you or the students to create a larger scope of study.

Design components of rocket:

- Fin number
- Fin shape
- Fin location

Design a vehicle for specific criteria:

- Design a rocket to reach a maximum velocity.
- Design a rocket to reach a maximum altitude.
- Design a rocket to reach a maximum velocity with a payload such as a paper clip.
- Design a rocket to reach a maximum altitude with a payload such as a paper clip.
- Design a rocket to reach a maximum range with a payload such as a paper clip.

Class Competition:

- Design a rocket to achieve the greatest range.
- Design a rocket to achieve the greatest altitude.
- Design a rocket to achieve a specific range.

Finding velocity:

- Use student-generated data from rocket launches to calculate the average velocity of each launch.
- Calculate the initial velocity of a straw rocket by launching the rocket straight up and measuring the time it is aloft.

Vocabulary

altitude

angle

apogee

average

conclusion

constraint

control

design

diameter

fin

hypothesis

inference

mass

modification

nose cone

projectile

range

rocket

scatter plot

trajectory

variable

weight

Glossary

altitude: the height above a reference point, usually the ground or sea level

angle: the figure formed by two lines extending from the same point

apogee: the highest altitude an object (such as a rocket) reaches during flight

average: the value provided by dividing the sum of a set of quantities by the number of quantities in the set

conclusion: an assumption or inference based on experimental data

constraint: a limit or restriction

control: an experiment in which all conditions are identical to those in a parallel experiment except for the omission of the condition or variable being tested; a control is used as a standard by which experimental effectiveness is judged

design: the process of creating

diameter: the distance from one side of a circle to the other passing through the center of the circle

fin: a winglike projection from the body of a rocket

hypothesis: a prediction based on prior knowledge or previous experimental data

inference: the act or process of deriving logical conclusions from premises known or assumed to be true

mass: the amount of matter within an object

modification: a change of the properties, form, or function

nose cone: the forward-most, usually separable, section of a rocket or guided missile that is shaped to offer minimum aerodynamic resistance and often bears protective cladding against heat

projectile: a fired, thrown, or otherwise propelled object

range: the horizontal distance traveled during projectile motion

rocket: a self-propelled device that carries its own fuel

scatter plot: a two-dimensional graph of two or more variables plotted on the y-axis or the x-axis to show their relationship(s)

trajectory: the curve described by a projectile in flight

variable: subject to changes; a quantity that may assume any of a set of values

weight: a measurement of the force that gravity exerts on a mass

Careers Related to Aerospace Design and Engineering

The activities in this unit are a small part of a larger field called aerospace design and engineering. Careers in or concerning aerospace design and engineering can be fun, challenging, and rewarding. Use the following links to see videos concerning aerospace design- and engineering-related careers. Then, explore the websites to learn more about other careers related to aerospace design and engineering.

- Aerospace Engineering and Operations Technicians: Pitsco.com/c-cv17-3021-00
- Aerospace Engineers: Pitsco.com/c-cv17-2011-00
- Team Assemblers: Pitsco.com/c-cv51-2092-00
- Mechanical Engineering Technicians: Pitsco.com/c-cv17-3027-00
- Physicists: Pitsco.com/c-cv19-2012-00
- Mathematicians: Pitsco.com/c-cv15-2021-00
- Avionics Technician: Pitsco.com/c-cv49-2091-00

Military Careers

Students may search the following sites for potential careers within the military related to straw rockets:

- Air Force: Pitsco.com/c-cv-mc-air-force
- Army: Pitsco.com/c-cv-mc-army
- Coast Guard: Pitsco.com/c-cv-mc-coast-guard
- Marine Corps: Pitsco.com/c-cv-mc-marine-corps
- National Guard: Pitsco.com/c-cv-mc-national-guard
- Navy: Pitsco.com/c-cv-mc-navy

Additional information about each career can be found by exploring the following websites:

- *Occupational Outlook Handbook*: Pitsco.com/c-ooh
- O*NET – Occupational Information Network: Pitsco.com/c-onet

Activity Suggestion

Have students create an "Aerospace and Rocketry Careers" pamphlet detailing career information such as skills required, nature of work, and level of education needed. Students should include information about at least two careers.

Careers

Pitsco.com/c/career.pdf

Students can use the "Careers" worksheet to help them gather information about a career by using the *OOH* and O*NET websites. They might find other related careers of interest they would like to explore. Print extra "Careers" worksheets if needed.

Careers

Occupational Outlook Handbook Research

Career Title: ______________________________

Career Summary			
Median Pay	**$**	**Current Number of Jobs**	
Lowest 10% Pay	**$**	**Projected Job Growth %**	
Highest 10% Pay	**$**		
What do people in this career do?			

What are the pros and cons of a career in this field? Justify your answer using information from the *OOH*.

Would you consider a career in this field? State the reasons for your decision. Cite evidence from the *OOH* that supports your decision. (For example: *I would not consider a career in this field. One of the reasons is that I do not like cold weather and the* OOH *states that these jobs exist only in regions close to the Arctic Circle.*)

Lab Report Template

Title

Abstract

The abstract is a short paragraph that summarizes your experiment. Include applicable information about your experimental subjects, materials and methods, results, and conclusions. The abstract is the part of the report that others will read to see if they are interested in the topic.

Introduction

The introduction should give background information on the experiment. It should include an explanation of the general problem or area being investigated. The introduction should outline what information is already known about the problem. In building this part of your report, you might want to consult references or, at the very least, reread the text. Be sure to keep track of the information and list all references used.

The introduction should also present the question you are trying to answer or the hypothesis you are testing. Include what outcome you expect and how it would support or disprove your hypothesis or answer your question. Distinguish between the hypothesis and the experiment you will do to test the hypothesis.

Materials and Methods

This section should include a concise, step-by-step numbered description of the materials, procedures, and equipment you used. Clearly describe the experimental situation, the control situation, and the type of observations you made. This should be detailed so that someone else could repeat your work. Do not include the rationale for your work in this section. Be sure to write this report as a past event, not as a set of instructions for the reader.

Results

This section should describe what happened. Include your raw data sheets or refer to the reference section of the report where they can be found. Present your findings in a logical order, not a chronological order. Give the results that you found, not what you think you should have found. Do not explain your results in this section. Results can be reported in the form of graphs, tables, or drawings. Be sure that the data recorded are single readings or averages.

Conclusion/Discussion

Give your interpretations of the data and relate them to the questions posed in the introduction. Avoid making this section a repetition of the introduction. If you have data to explain or a new hypothesis of why the results were unexpected, list them here.

Draw some conclusions, supporting them with your data. Did the results answer your question? Did they support or disprove your hypothesis? What is the significance of your results? Should further experiments be performed to clear up discrepancies or ambiguities in your results?

References

In this section, list the data that was concluded during the experiment. This could include graphs, charts, drawings, or data tables. In the Results section, you explained what happened; in this section, provide quantitative proof that your results are accurate.

Biography

Johannes Kepler

In an age of upheaval and commotion, Johannes Kepler overcame religious controversy and personal loss to become one of the greatest mathematicians and astronomers in history.

Born in 1571 in Weil der Stadt in what is now Germany, Kepler was raised Lutheran but did not agree with all Lutheran positions. He attended a nearby school, moved on to seminary, and earned a scholarship to the University of Tübingen. He passed his exams in 1591 but stayed on as a graduate student.

One of Kepler's teachers was Michael Maestlin, a leading astronomer of the time. Maestlin taught his advanced students – Kepler among them – about the Copernican system, which stated that the Sun was at the center of the solar system. At the time, the Ptolemaic system was the accepted theory; it stated that the planets and the Sun revolved around Earth.

Kepler accepted the Copernican theory, and much of his work was aimed at supporting it.

With Maestlin's encouragement, Kepler decided not to become ordained and instead became a mathematics teacher. In 1596, Kepler published the *Mystery of the Cosmos*, a cosmological theory he believed helped solidify the Copernican theory. He married at this time. In 1600, Protestants in the area were forced to leave, so Kepler accepted an assistant position to a highly regarded astronomer and imperial mathematician, Tycho Brahe, in Prague.

Brahe put Kepler to work on figuring out Mars' orbit. Orbits were thought to be circular, but this idea conflicted with some astronomical data.

Promoted to imperial mathematician after Brahe's death in 1601, Kepler continued to work on the Mars problem. He determined that Mars' orbit was an ellipse. This led to what is now known as Kepler's first law: Planets move in ellipses with the Sun at one focus. It also helped him form Kepler's second law: The radius vector describes equal areas in equal times. He published these laws in 1609.

Kepler's interests were not limited to the solar system. He was the first to accurately explain how the telescope and the human eye work. He learned that the Moon causes the tides and was the first to discover how logarithms work.

After learning so much about our world, Kepler's own world turned upside down. His son died in 1611, followed shortly by Kepler's wife. In 1612, the emperor was deposed by his brother, who was less tolerant of Protestants. So, Kepler left Prague and moved to Linz, where he served as district mathematician for 14 years. He remarried in 1613. In 1616, Kepler's mother was accused of witchcraft and he served in her defense; she was released in 1621. The Thirty Years War began in 1618, which put pressure on Protestants in the area.

During all this, however, Kepler continued working and published *Harmony of the World* in 1619. This work featured Kepler's third law: The squares of the periodic times are to each other as the cubes of the mean distances.

Kepler left his position in Linz in 1626. He died four years later in Regensburg, where he was trying to collect a debt.

Experimental Controls and Variables

Factors that affect an experiment are called variables. An experiment can have three kinds of variables: independent, dependent, and controlled. The independent variable is the variable that is purposely changed. The dependent variable is the variable that is observed. Measuring changes in the dependent variable should answer the question the experiment was designed to investigate. A variable that is not changed during the experiment is called a controlled variable.

For example, you might set up an experiment to test the effect of different types of light on the growth of plant seedlings. You might test the question, "Under which type of light do seedlings grow best?" The independent variable is the type of light the seedlings receive. The dependent variable is the change in height of each group of seedlings during the experiment.

For an experiment to be valid, it must be designed so that only the independent variable can cause the change in the dependent variable. Therefore, all variables except the independent variable must be controlled, or kept the same. In this experiment, controlled variables could include the type of seedling, type of soil, amount of water given, initial height of seedlings, amount of time between tests, and total length of the test.

Most experiments have at least two different test groups: one experimental group and one control group. Experimental groups are those being tested – the groups in which the independent variable is of special interest to the researcher. In your plant experiment, your experimental group might use a regular room light bulb as the light source. Control groups form a baseline to which the experimental group's results can be compared. In your experiment testing types of light, the light used in the control group might be regular sunlight since you know that plants grow well in regular sunlight.

More complex experiments can have more than one control group or more than one experimental group. In your plant experiment, you might test a second experimental group using a plant light, rather than a room light.

Notice that a control group is different from a controlled variable. The purpose of a controlled variable is to ensure that only the independent variable can be causing a change in the dependent variable. All groups – control and experimental – must have all variables controlled. The purpose of a control group is to provide a baseline for comparing changes in the experimental groups. Sometimes, these terms are used interchangeably and are called just controls, but you should understand the difference.

In any experiment, you should perform multiple tests. You should run the entire experiment several times. In each test run, both experimental and control groups should have as large a sample size as possible. In the plant experiment, testing 10 seedlings per group is better than testing only one per group. Averaging the results of multiple groups will even out any variations that might occur.

Velocity

Engineers and scientists use the term *velocity* to refer to how fast an object moves in a certain direction. This means that the velocity of a car would be its speed in a specific direction. For example, if a car is moving west at 65 mph, this is the car's velocity.

Mathematically speaking, speed and velocity are calculated using the same values. However, the difference between the two is the component of direction. This means that speed is a scalar quantity while velocity is a vector quantity.

Scalar quantities represent only size. For example, height, length, width, and volume would all be examples of scalar quantities. Vector quantities represent both size and direction.

There are two types of velocity: average and instantaneous. Average velocity is the velocity of an object over a distance and interval of time. It can be calculated by finding the ratio of the total distance traveled by the time it took to travel that distance.

$$\text{Average Velocity } (V) = \text{Total Distance Traveled } (D) \,/\, \text{Total Time } (T)$$

For example, if Denver and Kansas City are 975 kilometers apart and it takes 8 hours to drive from one city to the other, the average velocity will be:

$$V = 975 \text{ km}/8 \text{ h} = 121.9 \text{ km/h}.$$

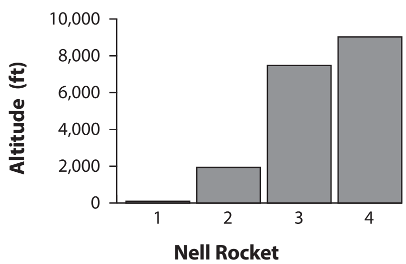
Instantaneous velocity is the velocity of an object at any instant in time. In our example – Denver to Kansas City – instantaneous velocity will differ from the average velocity due to the fact that the trip will not be traveled at a constant rate.

Graphing Data

The title of any graph should give a clear picture of what is represented by the graph.

Bar graphs have two axes. These axes are called the x-axis and the y-axis. The axes should be labeled. The labels should tell the reader what information is represented on the axes. The y-axis typically is used to show the value represented by the height of each bar. Bars are identified along the x-axis. Bars can represent people (as in a bar graph of students' test scores), places, things, or numeric values. Bars should be of equal width and should be separated by equal spaces.

Dr. Goddard's Rocket Experiments

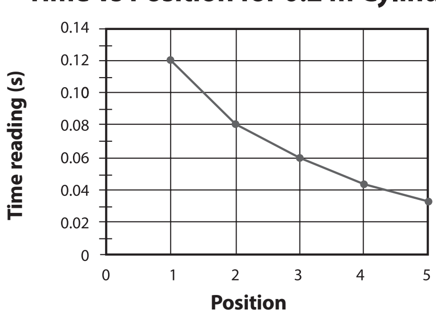


Bar graph example

Line graphs have an x-axis and a y-axis. These must be labeled so readers understand what is represented along the axes. Intervals along the x-axis should be consistent. Intervals along the y-axis should be consistent, but they do not have to be the same as the intervals along the x-axis. Points on a line graph are placed where the x value intersects the y value.

Trends can be analyzed on a line graph. The points on the line graph can show an upward or downward trend. They can also show a relationship that is proportional or inversely proportional. A proportional relationship means that when one value increases the other increases. An inversely proportional relationship means that when one variable increases the other decreases.

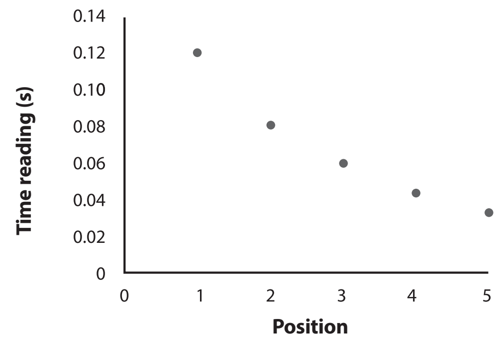
Time vs Position for 0.2 m Cylinder



Line graph example

Scatter plots are similar to line graphs and are often called x, y graphs because they are a graph of specific paired (x, y) data points. Scatter plots provide a graphic representation of the relationship between two data sets, one represented by the x value and the other represented by the y value.

Time vs Position for 0.2 m Cylinder



Scatter plot example

In a stem-and-leaf plot, the stem represents the number of tens. For example, 26 has a stem of 2 and a leaf of 6, since there are 2 tens and 6 ones. The number 100 would be represented with a stem of 10, since there are 10 tens. Each leaf represents the ones digit of each piece of data. The number 99 would have a stem of 9 and a leaf of 9, since there are 9 tens and 9 ones.

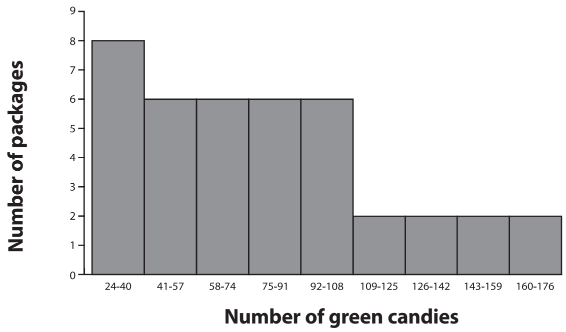
Height in Inches

4	77899
5	00034679
9	1111359
10	01113

Stem-and-leaf plot example

Histograms have two axes – an x-axis and a y-axis. These axes should also be labeled. The y-axis is divided equally. The y-axis represents the value of each bar. The x-axis displays the bins, or intervals, of each bar. The bins should be of equal size. To determine bin size, divide the range of the data set by the number of bins you would like to display. Round the quotient up. The bars in a histogram represent continuous data. Therefore, they are not separated by a space.

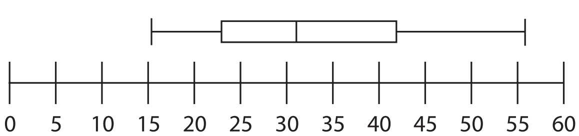
Number of Green Candies in a One-Pound Package



Histogram example

A box plot has only one axis. The axis is basically a number line from the lowest value to the highest value in the data set. The lower extreme is the lowest value in the data set. The lower extreme is labeled on the far left on the number line. The upper extreme is the highest value in the data set. The upper extreme is labeled on the far-right side of the number line. Lines from the box to the upper and lower extremes show the values in the set that fall outside the average. The lower quartile is the median of the lower half of values. The upper quartile is the median of the upper half of the data set. These values are used to create the sides of the box. The box shows the area in which the average falls.

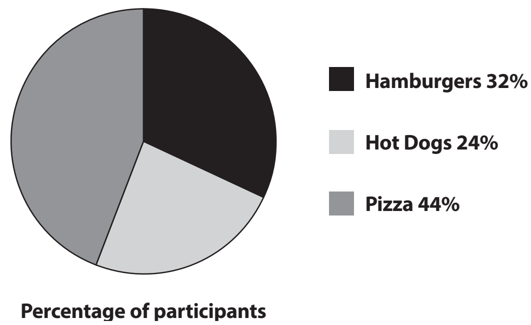
Age of Respondents



Box plot example

Circle graphs often have a legend. The legend is a guide to the information represented on the graph. Each section should have a specific color. The legend sometimes identifies the exact percent value of each section. Sections are created by multiplying 360 degrees by the percent value of the piece of data. The product is the number of degrees of the circle that represent the data. A protractor is used to divide the circle.

Food Preferences



Circle graph example

Additional Resources

Videos

Straw Rocket video: Pitsco.com/Straw-Rocket-Video

October Sky DVD: Pitsco.com/October-Sky-Video

Digital Resources

Straw Rocket Launcher Video: Pitsco.com/straw-rocket-launcher#videos

STEM Connections page: Pitsco.com/straw-rocket-launcher#resources

Straw Rockets Elementary STEM Success Story: Pitsco.com/c-straw-rockets-success-story

Straw Rocket Launcher User Guide: Pitsco.com/straw-rocket-launcher#resources

Straw Rocket Class Pack User Guide: Pitsco.com/straw-rocket-class-pack#resources

Essential Questions, Career Connections, Sample Activity: Pitsco.com/straw-rocket-maker-project#resources

Printable Resources

"Biography: Johannes Kepler" resource page: Pitsco.com/c/bio-jkepler.pdf

"Experimental Controls and Variables" resource page: Pitsco.com/c/experimental-controls-variables.pdf

"Velocity" resource page: Pitsco.com/c/velocity.pdf

"Graphing Data" resource page: Pitsco.com/c/graphing-data.pdf

"4Cs" resource page: Pitsco.com/c/4cs.pdf

Career Video Links: Pitsco.com/c/sr-career.pdf

Vocabulary List: Pitsco.com/c/sr-vocab.pdf

Pretest I: Pitsco.com/c/sr-pre1.pdf

Pretest I Answer Key: Pitsco.com/c/76393.pdf

Pretest II: Pitsco.com/c/sr-pre2.pdf

Pretest II Answer Key: Pitsco.com/c/38779.pdf

Posttest I: Pitsco.com/c/sr-post1.pdf

Posttest I Answer Key: Pitsco.com/c/19600.pdf

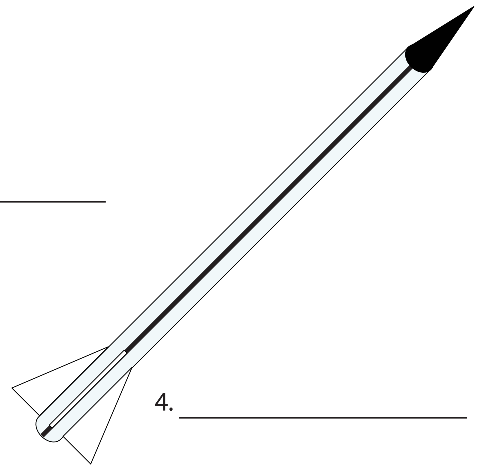
Posttest II: Pitsco.com/c/sr-post2.pdf

Posttest II Answer Key: Pitsco.com/c/91725.pdf

1. Which of the following terms means the horizontal distance traveled during projectile motion?

   A. mass
   B. altitude
   C. range
   D. trajectory

2-4. For Questions 2-4, label the following graphic with the names of the rocket components.



3. ______________________

2. ______________________

4. ______________________

5. If a rocket has three fins, how many degrees apart must each fin be in order to be equally spaced around the rocket's body?

6. Which of the following means a constraint with respect to a design?

   A. limit
   B. reasoned judgment
   C. detail
   D. rope

7. What propels a launched straw rocket?

8. In an experiment designed to test the effectiveness of a household cleaner, what would the variable(s) be?

9. In the experiment from Question 8, what would the controls be?

10. If a straw rocket launched at a 45-degree angle travels 35 feet in 1.4 seconds, what is the average velocity of the rocket's flight?

1. Which of the following terms means the horizontal distance traveled during projectile motion?

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   B. altitude D. trajectory

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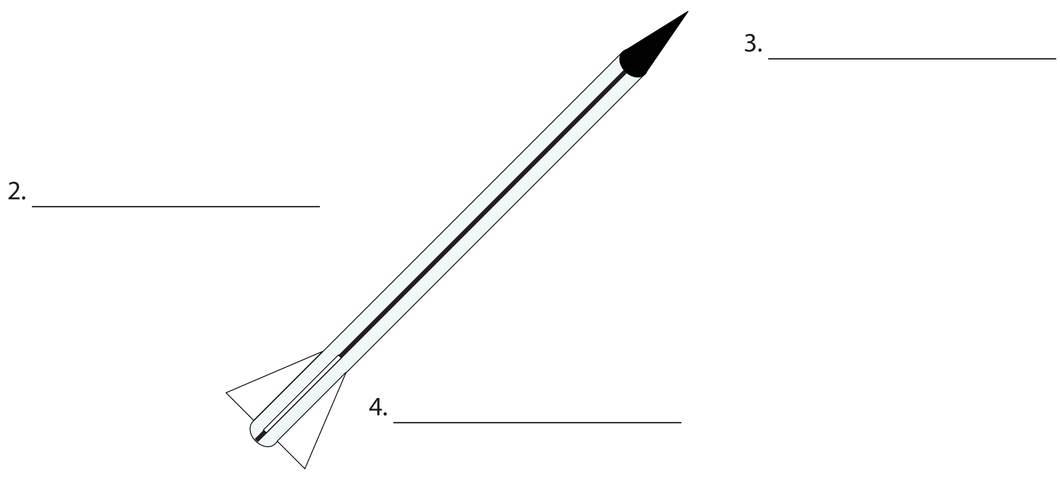

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1. What is the definition of a rocket's range?

2. If a rocket has five fins, how many degrees apart must each fin be in order to be equally spaced around the rocket's body?

3. What propels a launched straw rocket?

4. In an experiment designed to test the effectiveness of a household cleaner, what would the variable(s) be?

5. In the experiment from Question 4, what would the controls be?

6. With respect to a design, a constraint is ________________.

7. If two identical rockets are launched at the same angle but at different calibration lines, which rocket will have the greater range?

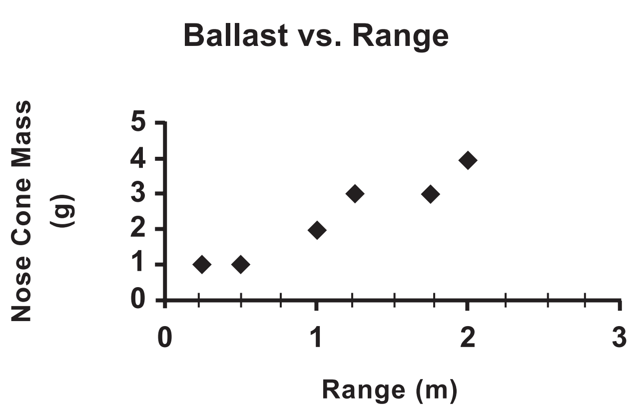
8. A projectile launched at which of the following angles will have the greatest range?

   A. 10 degrees   C. 20 degrees

   B. 45 degrees   D. 65 degrees

9. Rocket A is launched at 45 degrees using calibration mark 20 and achieves a range of 2 meters. Rocket B is launched at 45 degrees using calibration mark 20 and also achieves a range of 2 meters. Which rocket had the better performance?

10. In the following scatter plot, what was the average range of the rocket launches?



1. What is the definition of a rocket's range?

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3. What propels a launched straw rocket?

4. In an experiment designed to test the effectiveness of a household cleaner, what would the variable(s) be?

5. In the experiment from Question 4, what would the controls be?

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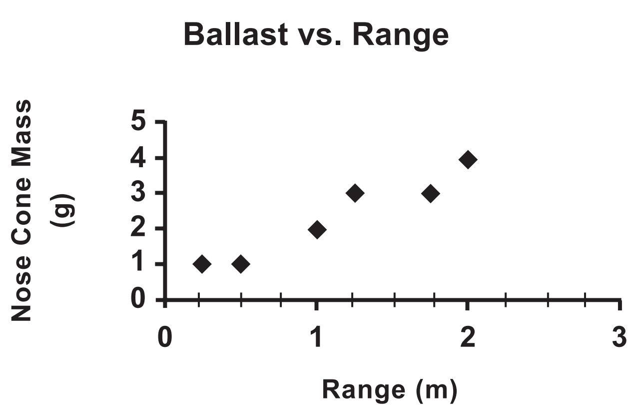

1. Which of the following terms means the horizontal distance traveled during projectile motion?

   A. mass
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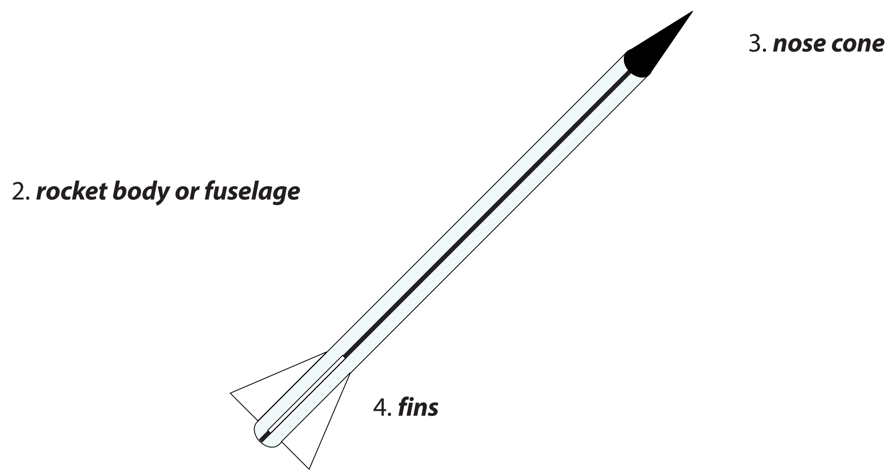


5. If a rocket has three fins, how many degrees apart must each fin be in order to be equally spaced around the rocket's body?

   120°

6. Which of the following means a constraint with respect to a design?

   A. limit
   B. reasoned judgment
   C. detail
   D. rope

7. What propels a launched straw rocket?

   air compressed by dropping the launch rod of the Straw Rocket Launcher (answers might vary)

8. In an experiment designed to test the effectiveness of a household cleaner, what would the variable(s) be?

   type or brand of cleaner (answers might vary)

9. In the experiment from Question 8, what would the controls be?

   surface being cleaned, temperature, type of grime (answers might vary)

10. If a straw rocket launched at a 45-degree angle travels 35 feet in 1.4 seconds, what is the average velocity of the rocket's flight?

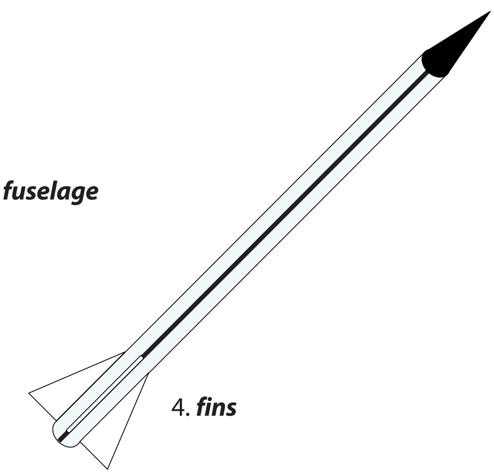
    25 feet per second

1. Which of the following terms means the horizontal distance traveled during projectile motion?

   A. mass — ***C. range***

   B. altitude — D. trajectory

2-4. For Questions 2-4, label the following graphic with the names of the rocket components.



3. ***nose cone***

2. ***rocket body or fuselage***

4. ***fins***

5. If a rocket has three fins, how many degrees apart must each fin be in order to be equally spaced around the rocket's body?

   120°

6. Which of the following means a constraint with respect to a design?

   A. limit — C. detail

   B. reasoned judgment — D. rope

7. What propels a launched straw rocket?

   air compressed by dropping the launch rod of the Straw Rocket Launcher (answers might vary)

8. In an experiment designed to test the effectiveness of a household cleaner, what would the variable(s) be?

   type or brand of cleaner (answers might vary)

9. In the experiment from Question 8, what would the controls be?

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10. If a straw rocket launched at a 45-degree angle travels 35 feet in 1.4 seconds, what is the average velocity of the rocket's flight?

    25 feet per second

1. What is the definition of a rocket's range?

   the horizontal distance traveled during projectile motion

2. If a rocket has five fins, how many degrees apart must each fin be in order to be equally spaced around the rocket's body?

   72°

3. What propels a launched straw rocket?

   air compressed by dropping the launch rod of the Straw Rocket Launcher (answers might vary)

4. In an experiment designed to test the effectiveness of a household cleaner, what would the variable(s) be?

   type of brand of cleaner (answers might vary)

5. In the experiment from Question 4, what would the controls be?

   surface being cleaned, temperature, type of grime, and so forth (answers might vary)

6. With respect to a design, a constraint is ________________.

   a limit

7. If two identical rockets are launched at the same angle but at different calibration marks, which rocket will have the greater range?

   the rocket launched from the higher calibration mark

8. A projectile launched at which of the following angles will have the greatest range?

   A. 10 degrees　　C. 20 degrees

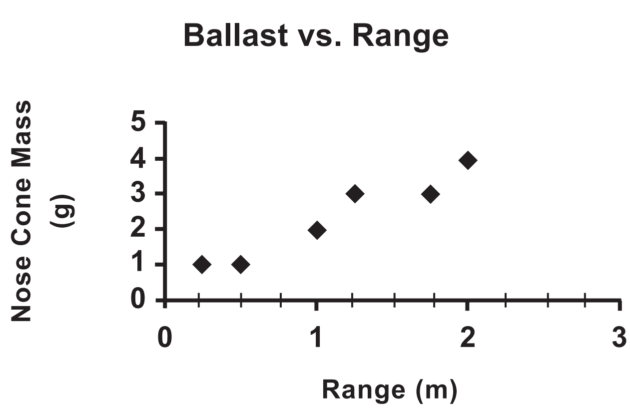
   B. 45 degrees　　D. 65 degrees

9. Rocket A is launched at 45 degrees using calibration mark 20 and achieves a range of 2 meters. Rocket B is launched at 45 degrees using calibration mark 30 and also achieves a range of 2 meters. Which rocket had the better performance?

   Rocket A

10. In the following scatter plot, what was the average range of the rocket launches?

    1.125 meters



1. What is the definition of a rocket's range?

   the horizontal distance traveled during projectile motion

2. If a rocket has five fins, how many degrees apart must each fin be in order to be equally spaced around the rocket's body?

   72°

3. What propels a launched straw rocket?

   air compressed by dropping the launch rod of the Straw Rocket Launcher (answers might vary)

4. In an experiment designed to test the effectiveness of a household cleaner, what would the variable(s) be?

   type of brand of cleaner (answers might vary)

5. In the experiment from Question 4, what would the controls be?

   surface being cleaned, temperature, type of grime, and so forth (answers might vary)

6. With respect to a design, a constraint is ________________.

   a limit

7. If two identical rockets are launched at the same angle but at different calibration marks, which rocket will have the greater range?

   the rocket launched from the higher calibration mark

8. A projectile launched at which of the following angles will have the greatest range?

   A. 10 degrees C. 20 degrees

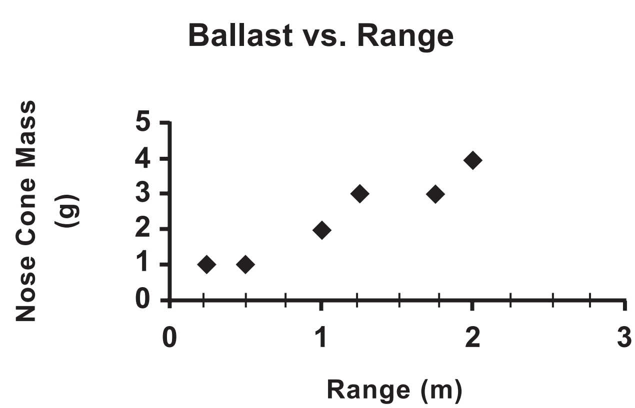
   B. 45 degrees D. 65 degrees

9. Rocket A is launched at 45 degrees using calibration mark 20 and achieves a range of 2 meters. Rocket B is launched at 45 degrees using calibration mark 30 and also achieves a range of 2 meters. Which rocket had the better performance?

   Rocket A

10. In the following scatter plot, what was the average range of the rocket launches?

    1.125 meters

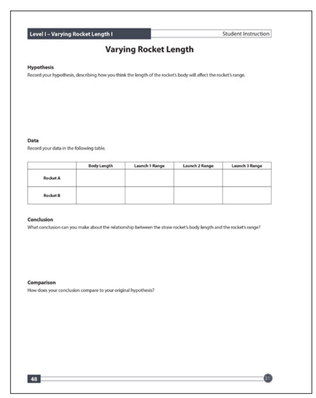


Quick View

Vary the length of a straw rocket to investigate the effect length has on the rocket's range.

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- "Varying Rocket Length" worksheet
- "Experimental Controls and Variables" resource page (optional)
- Range paper (optional)
- Caplugs (optional)


Level I – Varying Rocket Length I
Student Instruction

Varying Rocket Length

Hypothesis

Record your hypothesis, describing how you think the length of the rocket's body will affect the rocket's range.

Data

Record your data in the following table.

	Body Length	Launch 1 Range	Launch 2 Range	Launch 3 Range
Rocket A				
Rocket B				

Conclusion

What conclusion can you make about the relationship between the straw rocket's body length and the rocket's range?

Comparison

How does your conclusion compare to your original hypothesis?

48

Procedure

1. Locate the "Varying Rocket Length" worksheet and write a hypothesis stating how you think variations in the length of the rocket's body will affect the rocket's range.
2. Construct two straw rockets of different lengths. The difference in lengths should be a minimum of five centimeters and a maximum of 10 centimeters. The other main components should be the same for both rockets (for example, same number of fins, same fin size and shape, same nose cone size and shape) and should stay within the design constraints (see the Construction Quick View for design constraints).
3. Label one rocket "Rocket A" and the other rocket "Rocket B."
4. Slip Rocket A over the launch tube.
5. Adjust the launch tube and rocket to the trajectory angle of 45 degrees.
6. Raise the launch rod calibration mark 20 (calibration marks are the black lines on the launch rod).
7. To launch, release the launch rod so that it falls to the bottom of the cylinder.
8. Measure the rocket's range using the tape measure.
9. Record the rocket's range on the worksheet.
10. Repeat Steps 4-9 twice more for Rocket A and three times for Rocket B.
11. Analyze the data generated from the launches and write a conclusion explaining how the difference in rocket body length affects the rocket's range. Compare your hypothesis to your conclusion.

Varying Rocket Length

Hypothesis

Record your hypothesis, describing how you think the length of the rocket's body will affect the rocket's range.

Data

Record your data in the following table.

	Body Length	Launch 1 Range	Launch 2 Range	Launch 3 Range
Rocket A				
Rocket B				

Conclusion

What conclusion can you make about the relationship between the straw rocket's body length and the rocket's range?

Comparison

How does your conclusion compare to your original hypothesis?

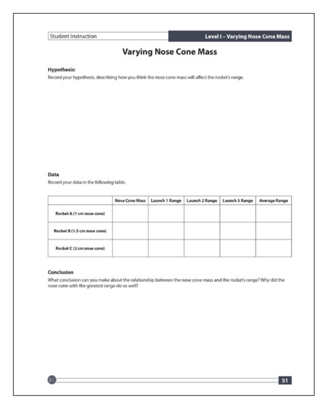
Quick View

Vary the mass of the nose cone to investigate the effect on the rocket's range.

Materials

- Pitsco Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- Calculator
- Digital scale
- "Varying Nose Cone Mass" worksheet
- "Experimental Controls and Variables" resource page (optional)
- Range paper (optional)

Note: Caplugs should not be used in this activity. Modeling clay is required.



Procedure

1. Locate the "Varying Nose Cone Mass" worksheet and write a hypothesis stating how you think variations in the nose cone mass will affect the rocket's range.
2. Follow the design constraints in the Construction Quick View to construct one straw rocket of your choice, except for the nose cone. You will design three varying nose cones for this rocket.
3. The first nose cone design must be created from a ball of clay one centimeter in diameter. It may have whatever shape you choose. Measure the mass of this clay ball and record it.
4. Create two more nose cones, one from a ball with a diameter of 1.5 centimeters and another with a diameter of two centimeters. These should be the same shape as the first design. Measure and record the mass of these clay balls.
5. Place the smallest nose cone onto the straw rocket body you created in Step 2. Slip the rocket over the launch tube.
6. Adjust the launch tube and rocket to the trajectory angle of 45 degrees.
7. Raise the launch rod to calibration mark 20.
8. To launch, release the launch rod so that it falls to the bottom of the cylinder.
9. Measure the rocket's range using the tape measure.
10. Record the rocket's range on the worksheet.
11. Repeat Steps 5-10 twice more for the smallest nose cone and three times each for the other two nose cones.
12. Complete the worksheet, including calculating the average range for each nose cone.
13. Analyze the data generated from the launches and write a conclusion explaining how the difference in nose cone mass affects the rocket's range. Also explain why you think the nose cone that achieved the greatest range did so.

Varying Nose Cone Mass

Hypothesis:

Record your hypothesis, describing how you think the nose cone mass will affect the rocket's range.

Data

Record your data in the following table.

	Nose Cone Mass	Launch 1 Range	Launch 2 Range	Launch 3 Range	Average Range
Rocket A (1 cm nose cone)					
Rocket B (1.5 cm nose cone)					
Rocket C (2 cm nose cone)					

Conclusion

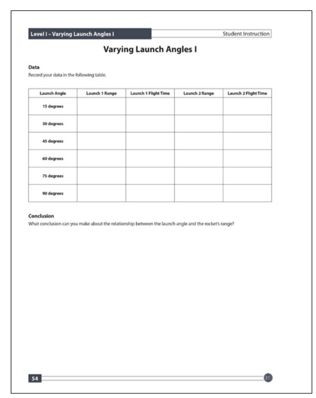
What conclusion can you make about the relationship between the nose cone mass and the rocket's range? Why did the nose cone with the greatest range do so well?

Quick View

Vary the angle of launch to investigate the effects angle has on the rocket's range.

Materials

- Straw Rocket Launcher
- Completed straw rocket
- Ruler
- Tape measure
- Stopwatch
- Pencil
- "Varying Launch Angles I" worksheet
- Range paper (optional)
- Caplugs (optional)



Level I – Varying Launch Angles I Student Instruction

Varying Launch Angles I

Data

Record your data in the following table.

Launch Angle	Launch 1 Range	Launch 1 Flight Time	Launch 2 Range	Launch 2 Flight Time
15 degrees				
30 degrees				
45 degrees				
60 degrees				
75 degrees				
90 degrees				

Conclusion

What conclusion can you make about the relationship between the launch angle and the rocket's range?

54

Procedure

1. Locate the "Varying Launch Angles I" worksheet. Be sure to look over the entire worksheet as there are multiple pieces of information that you will need to collect from each launch.
2. Slip your completed rocket over the launch tube.
3. Adjust the launch tube and rocket to the trajectory angle of 15 degrees.
4. Raise the launch rod to calibration mark 20.
5. To launch, release the launch rod so that it falls to the bottom of the cylinder.
6. As soon as the rocket launches, start the stopwatch so it will time the rocket's flight. Stop timing as soon as the rocket hits the ground.
7. Measure the rocket's range using the tape measure.
8. Record the rocket's range and flight time on the worksheet.
9. Launch the rocket one more time from the trajectory angle of 15 degrees.
10. Record the second launch's information on the worksheet.
11. Repeat Steps 2-10 using trajectory angles of 30 degrees, 45 degrees, 60 degrees, 75 degrees, and 90 degrees.
12. Complete the worksheet.
13. Analyze the data generated from your tests and write a conclusion explaining how the difference in launch angles affects the rocket's range.

Varying Launch Angles I

Data

Record your data in the following table.

Launch Angle	Launch 1 Range	Launch 1 Flight Time	Launch 2 Range	Launch 2 Flight Time
15 degrees				
30 degrees				
45 degrees				
60 degrees				
75 degrees				
90 degrees				

Conclusion

What conclusion can you make about the relationship between the launch angle and the rocket's range?

Quick View

Design a straw rocket that will achieve the greatest range possible.

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- Graph paper
- Digital scale
- Notebook
- Engineering Design Loop poster set (optional)
- Range paper (optional)
- Caplugs (optional)

Procedure

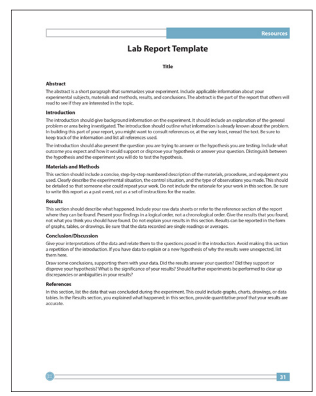
1. Design a straw rocket. Determine fin shape, number of fins, rocket length, and nose cone shape. Below are the design constraints applied to the rocket for this challenge.
   - Rockets should have a minimum of two fins and a maximum of five fins.
   - The body of the rocket should be a minimum length of 10 centimeters and a maximum length of 20 centimeters.
   - The amount of clay used for the nose cone should have a minimum mass of one gram.
2. Sketch the rocket design on a piece of graph paper, starting with the rocket body. Proceed to the fins and finish with the nose cone. Use a ruler to determine the dimensions of the materials.
3. Construct your straw rocket.
4. Test your rocket. Complete at least three test launches with your rocket at the launch angle of your choice. Use the tape measure to measure the range achieved on each launch. Record the measurements and a description of your design in a notebook.
5. Evaluate the strengths and weaknesses of your design. Make changes to the design based on the data from the test launches. Note the changes made. Use sketches and/or written paragraphs. Include a date and time with each entry.
6. Construct your straw rocket, making any design changes.
7. Test the redesigned rocket. The goal is to achieve the maximum range possible. Complete three test launches at the launch angle of your choice. You might make minor adjustments between launches if necessary. Record the ranges in your notebook. Also, track any repairs or modifications made between launches.
8. Compare the ranges achieved by the redesigned rocket with the ranges achieved by the original design. Evaluate the results.
9. Write a report summarizing the design and testing process you went through. Include which design was most successful. Give reasons that you think that design was successful, including any factors that you feel might have contributed to the success or failure of the designs.

Quick View

Experiment with the length of a straw rocket to test the effect length has on the rocket's range.

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Graph paper
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- Digital scale
- "Lab Report Template" resource page
- "Experimental Controls and Variables" resource page (optional)
- Range paper (optional)
- Caplugs (optional)


Resources
Lab Report Template
Title
Abstract
Introduction
Materials and Methods
Results
Conclusion/Discussion
References

Procedure

1. Design an experiment to test the effects of body length on the rocket's range.
2. Design and construct a minimum of two and a maximum of four straw rockets where the only variable is the rocket body length. However, every component of the rocket must meet the following design constraints:
    - Rockets should have a minimum of two fins and a maximum of five fins.
    - The body of the rocket should be a minimum length of 10 centimeters and a maximum length of 20 centimeters.
    - The amount of clay used for the nose cone should have a minimum mass of one gram and a maximum mass of five grams.
3. Launch each rocket at least twice.
4. Record the data from each launch.
5. Complete a write-up of your experiment using the "Lab Report Template" resource page.

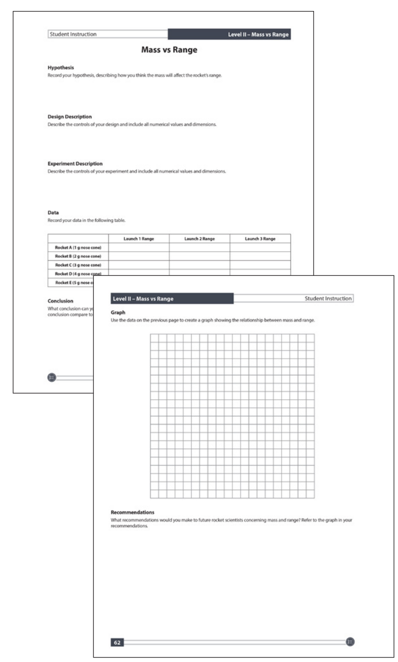
Quick View

Change the mass of a straw rocket to increase the rocket's range.

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Digital scale
- Pencil
- "Mass vs. Range" worksheet
- "Experimental Controls and Variables" resource page (optional):
- "Graphing and Data" resource page (optional): Pitsco.com/c/graphing-data.pdf
- Range paper (optional)

Note: Caplugs should not be used in this activity. Modeling clay is required.


Student Instruction
Level II – Mass vs Range
Mass vs Range
Hypothesis
Design Description
Experiment Description
Data
Conclusion
Level II – Mass vs Range
Student Instruction
Graph
Recommendations

Procedure

1. Locate the "Mass vs. Range" worksheet and write a hypothesis stating how you think variations in the rocket mass will affect the rocket's range.
2. Construct one 15-centimeter-long straw rocket with a minimum of two fins and a maximum of five fins.
3. Add a one-gram clay nose cone to the rocket.
4. Perform three launches at a 45-degree launch angle and a calibration mark of 20. Record the ranges on the worksheet.
5. Remove the one-gram nose cone and replace it with a two-gram nose cone. Perform three launches with the same launch angle and calibration mark. Record the results.
6. Repeat the process with three-gram, four-gram, and five-gram nose cones, keeping the angle and calibration marks the same. Record all results.
7. Analyze the data generated from your tests and write a conclusion explaining how the difference in mass affects the rocket's range. Create a graph of your experimental data. Based on this graph, make a recommendation concerning mass and rocket range to future rocket scientists.

Mass vs Range

Hypothesis

Record your hypothesis, describing how you think the mass will affect the rocket's range.

Design Description

Describe the controls of your design and include all numerical values and dimensions.

Experiment Description

Describe the controls of your experiment and include all numerical values and dimensions.

Data

Record your data in the following table.

	Launch 1 Range	Launch 2 Range	Launch 3 Range
Rocket A (1 g nose cone)			
Rocket B (2 g nose cone)			
Rocket C (3 g nose cone)			
Rocket D (4 g nose cone)			
Rocket E (5 g nose cone)			

Conclusion

What conclusion can you make about the relationship between the rocket's mass and the range achieved? How does this conclusion compare to your original hypothesis?

Graph

Use the data on the previous page to create a graph showing the relationship between mass and range.

Recommendations

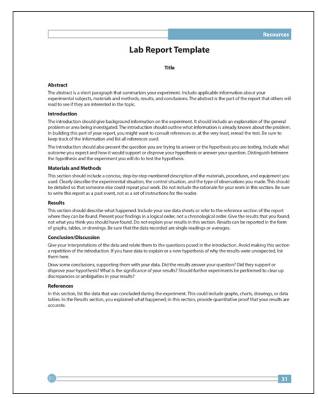
What recommendations would you make to future rocket scientists concerning mass and range? Refer to the graph in your recommendations.

Quick View

Experiment with the launch angle of a straw rocket to test the effect angle has on the rocket's range.

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Scissors
- Transparent tape
- Ruler
- Tape measure
- Pencil
- Digital scale
- "Lab Report Template" resource page
- "Experimental Controls and Variables" resource page (optional)
- Range paper (optional)
- Caplugs (optional)



Procedure

1. Design an experiment to test the effects of launch angle on the rocket's range.
2. Design and construct one straw rocket. Every component of the rocket must meet the following design constraints:
    - Rockets should have a minimum of two fins and a maximum of five fins.
    - The body of the rocket should have a minimum length of 10 centimeters and a maximum length of 20 centimeters.
    - The amount of clay used for the nose cone should have a minimum mass of one gram.
3. Launch the rocket from a minimum of five different angles. Complete two launches at each angle.
4. Record the data from each launch.
5. Complete a write-up of your experiment using the "Lab Report Template" resource page.

Quick View

Design a straw rocket that will achieve a specified range.

Materials

- Straw Rocket Launcher
- Precision Straws
- Index cards
- Modeling clay
- Ruler
- Tape measure
- Scissors
- Transparent tape
- Pencil
- Graph paper
- Digital scale
- Notebook
- Engineering Design Loop poster set (optional)
- “Experimental Controls and Variables” resource page (optional)
- Range paper (optional)
- Caplugs (optional)

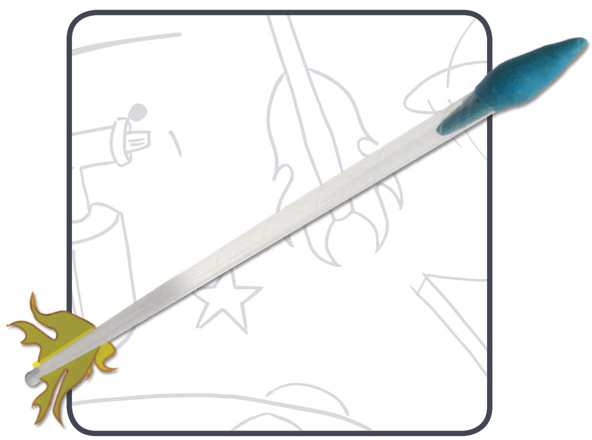
Procedure

1. Build a standard straw rocket while staying within the design constraints in the Construction Quick View.
2. Develop a process for testing the straw rocket. In particular, test specifications in the design of the rocket that could be altered to change the range achieved by the rocket. For example, test whether or not the number of fins on the rocket affects the range the rocket travels or if the shape of the nose cone affects the range. Record your testing data in a notebook.
3. Refer to your testing data. Record any inferences or conclusions you can make about how range is affected by different design specifications.
4. Test your theories.
5. Evaluate your theories and retest if necessary.
6. Build a rocket to travel a specific range. Your teacher will determine the range.
7. Test the rocket.
8. Complete three launch trials. Record how close you were to the target range.
9. Write a report summarizing the design and testing process you went through. Give reasons why you think your design was successful or unsuccessful. Include factors that might have contributed to the success or failure of the designs.

STRAW ROCKETS

Teacher's Guide

STEM Curriculum for Straw Rockets



HAVE QUESTIONS?

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Call us at 800-358-4983.
Email us at orders@pitsco.com.
Chat with us on Pitsco.com/support.

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